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Material Selection: Tools, Resources, and Techniques for Choosing Green

Choosing the right materials for a building is no easy task under any circumstances. Just meeting the conventional criteria, such as performance, cost, and aesthetics, can be a challenge; the addition of an environmental agenda further complicates the picture. The good news is that more tools and resources are becoming available to help designers select the most benign materials.

No generic resource can anticipate all the demands and constraints of a particular project, so ultimately the designer or specifier must use the available information and make his or her own decision. In this article we review the various tools that have been developed to help with material selection, and then outline *EBN*'s technique for streamlining the decision-making process.

The Whole Product Life-Cycle Matters

Whether it is explicit or implicit, every approach that considers materials from an environmental perspective uses some form of life-cycle analysis or life-cycle assessment (LCA). The LCA process is based on a life-cycle inventory, in which a researcher identifies and quantifies all of the raw materials and energy consumed in the production, use, and disposal of the product, as well as pollutants and by-products generated. Depending on the available data and resources, this inventory may be comprehensive and detailed, or cursory, looking only to the most significant inputs and outputs.

Following the inventory, the LCA examines the environmental impacts of each of these material and energy flows. This step is as much an art as a science, because it involves the nearly impossible task of tracking ecological impacts as they ripple endlessly through the world's natural systems. LCAs done for specific products may include a final step: identifying areas for improvement.

Given the level of complexity involved in analyzing the life-cycle of a specific product, it is not surprising that such tasks are usually undertaken only by relatively large manufacturers who are committed to learning about and reducing the environmental impacts of their processes. Unfortunately, such detailed information is rarely made available to the public. Even if it were, it is unlikely that architects and specifiers—who must make decisions about hundreds of products for each project—would be able to digest and utilize such massive amounts of information. In addition, if detailed information is available for a product from one manufacturer but not from the competitors, the designer still has no way of determining which of those products has the lower impacts and is thus a better environmental choice.

To help with this situation, researchers around the world are creating simplified LCAs for building materials. These assessments are done for generic materials rather than specific products, so they are usually very rough in LCA terms. They analyze the flows of materials and energy that are considered typical in each industry, and the environmental impacts that commonly stem from those flows. While recognizing that such a simplified, generic LCA can never be as accurate as a detailed product

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In This Issue:

Outrageous quote of the month:

"Halogen lighting is the most efficient available light source today."

Material Selection *(from page 1)*

LCA, the streamlined material information can still provide a very good starting point for comparing materials.

Published Tools

A range of resources from around the world is becoming available to assist designers in the process of material selection. Some of the best publications available in English are described in the table on page 11. Several software tools, offering more flexibility in terms of how the information can be formatted and used, will soon be available as well.

Each of these resources and tools has its own strengths and weaknesses. Publications and directories that direct users to specific products represent a whole different category, which will be surveyed in a future issue.

Information or answers?

Resources designed to help with the task of building material selection all have to deal with the question of how much background information to provide. Ideally, they would present all the impacts in detail, giving designers enough information to make their own decisions. This approach isn't realistic, however, because the natural world is so complex that all of the impacts can never be fully known, so value judgments and expert opinions will always be necessary. Even if all the factors were knowable, designers are usually under pressure to make decisions quickly and move on, so they aren't free to digest a lot of raw information.

One of the most memorable comments we've received at *EBN* from one of our subscribers is: "Enough with all the eco-babble, just give the answers!" Some of these resources try to do just that—provide only answers. There are two main problems to this approach. First, without knowing exactly how these answers were reached, we can't tell how trustworthy they are. Second, we can't know how to apply these answers when conditions are slightly different. For example, we might read that poured concrete is the best choice for a basement wall. But what about a shorter, crawl-space wall? Or what if the wall must be insulated—is concrete still the best choice?

Without knowing how the original assessment was made, we can't extrapolate from it to fit the specifics of our own situation.

Ratings and rankings

Most of the publications that provide answers to the building material selection problem do so in the form of ratings or rankings of the alternatives for a particular application. These approaches may try to synthesize all the considerations into one overall ranking hierarchy—providing just a single "answer"—or they may break out the various environmental areas of concern and rank each material separately for each of those areas—providing more information for the user (see table).

The text that usually accompanies these ranking charts varies from a few paragraphs summarizing the most significant findings, to detailed explanations of each item. In addition to listing the top choices, some reports also provide guidance on how each material can be specified or detailed to optimize its performance and minimize its environmental shortcomings.

Any day now… (the "Vaporware" update)

Several software tools are being developed to provide assistance with building material selection. The long-awaited Optimize™ program from Canada Mortgage and Housing Corporation contains extensive embodied energy data on materials. It is now slated for release early in 1997, according to project manager Peter Russell. Also from Canada is the Athena™ building materials database, which has very detailed lifecycle information on a limited number of materials. Forintek Canada Corp. is still trying to decide when and how to make Athena publicly available.

Meanwhile, Barbara Lippiatt of the U.S. National Institute of Standards and Technology (NIST) is developing the "Building for Environmental and Economic Sustainability" (BEES) database (see *EBN* Vol. 4, No. 5). Plans for BEES are greatly scaledback from their original goals, at least in the short term. This initial version of BEES, due out in December 1997, includes just fifteen materials, and doesn't address environmental concerns that are hard to quantify, such as habitat alteration, biodiversity, and indoor air quality impacts.

Unlike these building material-specific programs, several more general LCA databases are currently available, covering materials used in many industries. These are not appropriate for use by most building designers, however, because of their high cost, training requirements, and limited building-related data. Various efforts are being considered to make some of these general LCA databases more applicable to building design. For example, Santa Cruz, California architect Hal Levin is working on such modifications with developers of the Dutch EcoQuantum program.

Resources on Environmental Impacts of Materials

Publication info	# materials compared	Background info	Type of ranking	Source of the data	Comments
EBN Feature Articles on Materials	16 detailed material articles as of 1/97, addressing about 50 different materials	Moderate to Extensive	None	Published literature, communication with experts and manufacturers	Recommendations often provide guidance on how best to use each material; specific products are mentioned by name.
Environmental Resource Guide Joseph Demkin, editor, The American Institute of Architects; John Wiley & Sons	26 detailed Material Reports; 8 Application Reports comparing a total of 55 materials (1997 edition)	Very extensive—detailed reports and tables explaining all ratings	White-gray-black in 14 environmental categories, plus split rankings where design can affect performance	Published literature, communication with experts and manufacturers	Recommendations also provide guidance on how best to use each material. Application Reports are compiled by EBN editors Wilson and Malin. See *EBN* Vol. 5, No. 2 for a full review.
Handbook of Sustainable Building James & James Science Publishers (U.K.), PO Box 605, Herndon, VA 22070; 703/435-7064, 703/689-0660 (fax)	80 sections, each comparing 3-7 materials (April 1996 edition)	Moderate: little detail with rankings, but some background material in a later section	1st, 2nd, and 3rd choices, and "not recommended" for most materials. Also a "basic selection" considering cost, availability	Proprietary LCA database	British translation of Dutch text. Good introductory overview on sustainable construction. Ratings are in two parts, one for new construction and one for renovation.
Building material Ecological Sustainability Index Partridge Partners, 23 Ben Boyd Road, Neutral Bay, NSW 2089, Australia; +61 2 9923 1788, +61 2 9929 7096 (fax) ecostruc@zeta.org.au	29 materials and 23 building components (assemblies) (December 1995 edition)	Limited: brief comments within the table, good introduction on the methodology	1 to 5 in 16 categories, combined into total scores for 3 major categories, and further calculated for complete assemblies	Authors' research, published data	Sophisticated weighting system for environmental categories—each area of concern is given a weighting factor that becomes part of the scoring formula. Use phase is excluded from the analysis.
The Green Guide to Specification by David Shiers, Nigel Howard, and Mike Sinclair. Contact: David Shiers, Oxford Brookes Univ., Oxford, OX3 0BP, U.K.; +44 1 865 483446, +44 1 865 483927 (fax)	19 comparisons (some of materials, some of assemblies) each listing 4-12 options (some repetitions) (March 1996 edition)	Limited: a brief introduction to each section summarizing the findings	A – C in 16 environmental areas of concern, with a summary ranking	Proprietary LCA database	Includes specific cost information, and lists the maintenance and replacement intervals that are assumed for the ratings. All environmental areas of concern are weighted equally for the summary rating.
Green Building Digest Sam Kimmins, editor; ACTAC–The Technical Aid Network, 64 Mount Pleasant, Liverpool, L3 5SD, U.K.; +44 151 708-7607, +44 151 708-7606 (fax), actac@mail.cybase.co.uk	13 reports (issues) each comparing 6-12 materials (as of December 1996)	Moderate: Explanation of the ratings in the main matrix, and section on alternatives	0 – 4 in 11 environmental categories, plus a "positive impacts" option	Published literature, editor's knowledge	Informal, humorous style; each issue covers one application or component. Unit factor multiplier provides cost information. "Best Buy" section summarizes the recommendations.

Hierarchy of Life-cycle Stages

1. **Construction and use**
2. **Manufacturing**
3. **Raw material acquisition and preparation**
4. **Disposal/Reuse**

EBN's Simplified Method

Feature articles on materials published in *Environmental Building News* don't provide formal rankings, but they aim to help designers focus on the most important issues in an accessible format. Only a few dozen materials have been covered in such articles to date, but developing these articles has lead to the creation of a methodology which knowledgeable designers can use to guide their own decision-making process.

Outlined below is *EBN*'s simplified methodology for choosing the most benign materials. It is important to note that the results of this process can only be as good as the knowledge-base of those using it. These steps cannot take the place of a thorough understanding of the life-cycles of the materials and their environmental impacts—they only offer a methodical way to apply that knowledge. This is a work-in-progress that evolves each time we use it, and we welcome any and all ideas for modifications and improvements.

Hierarchy of life-cycle stages

The twelve steps of this method span the life cycle of the materials in question, but not in their natural order. While the LCAs of many consumer products focus on the production and disposal issues, in the case of many building materials it is the *use* phase of the product that is most significant because of the relatively long lifetime over which building materials are in use. In this sense, Joel Todd, whose Scientific Consulting Group writes the material reports for the *Environmental Resource Guide*, refers to building materials as having a "use-dominated life cycle." This does not mean that the use phase is the most important stage for every material one might consider, but it does suggest that in many cases this is where the most significant environmental considerations can be found.

Following the use phase, the manufacturing or production stage is usually the most important, especially for the highly processed or manufactured materials that are increasingly common. Many of these materials may contain hazardous or toxic components, or generate toxic intermediaries as part of their production process.

The raw materials extraction and preparation phase is typically next in importance. Finally, the disposal stage can be important due to the shear volume of material that buildings embody. It falls at the end of this list, however, because of the long useful life of most building materials and the recyclability of many of them. Additionally, much of a building's mass can be utilized as clean fill, so the potential impact on solid waste landfills is mitigated.

It is important to note that while this hierarchy is a useful guide, it is not meant to suggest that all materials will have their environmental burdens ranked in this order. For materials that are used in a natural or minimally processed state, such as wood or stone, the raw material extraction phase may be more significant than the first two, while the most significant impacts of many synthetic materials may be found in the manufacturing stage. And a few products, such as preservative-treated wood, may be most problematic in the fourth stage, disposal.

The first three steps: the use phase

Two of the most significant sources of environmental impact from building materials are energy use in the building and possible impacts on occupant health. Considerations of impacts in the use phase depend not only on the material in question, but also on the application for that material.

Step 1 – Energy use: Will the material in question (in the relevant application) have a measurable impact on building energy use? If not, proceed to step 2.

If yes (as for materials such as glazing, insulation, mechanical systems), avoid options that do not minimize energy use. Also take care to design the application to minimize energy use. For materials that can be used in an energy-efficient manner only with the addition of other components, the impact of including those additional components must be factored in. Examples include glazing systems that require exterior shading systems for efficiency, and light-gauge steel framing that requires foam sheathing to prevent thermal bridging.

Step 2 – Occupant health: Might products in this application affect the health of building occupants? If not, proceed to step 3.

If yes (interior furnishings, interior finishes, mechanical systems), avoid materials that are likely to adversely affect occupant health, and design systems to minimize any possible adverse effects when sources of indoor pollution cannot be avoided.

Step 3 – Durability and maintenance: Are products in this application likely to need replacement, special treatment, or repair multiple times during the life of the structure? If not, proceed to step 4.

If yes (roofing, coatings, sealants), avoid products with short expected lifespans (unless they are made from low-impact, renewable materials and are easily recycled), or products that require frequent, high impact maintenance procedures. Also, design the structure for flexibility so that materials that might become obsolete before they wear out (such as wiring) can be replaced with minimal disruption and cost.

Next steps: manufacturing

The remaining steps pertain less to the application (how a material or product is used) and more to the material itself. They require knowledge of the raw materials that go into each product.

Step 4 – Hazardous by-products: Are significant toxic or hazardous intermediaries or by-products created during manufacture, and if so, how significant is the risk of their release to the environment or risk of hazard to worker health? If these are not significant, proceed to step 5.

Where toxic by-products are either generated in large quantities or in small but uncontrolled quantities (smelting of zinc, production of petrochemicals), the building material in question should be avoided if possible, or sourced from a company with strong environmental standards.

Step 5 – Energy use: How energy-intensive is the manufacturing process? If not very intensive, proceed to step 6.

If the manufacture of a building material is very energy-intensive compared to the alternatives (aluminum, plastics), its use should be minimized. It is not the energy use itself that is of concern, however, but the pollution from its generation and use; industries using clean-burning or renewable energy sources have lower burdens than those relying on coal or petroleum.

Step 6 – Waste from manufacturing: How much solid waste is generated in the manufacturing process? If not much relative to the quantity of product manufactured, proceed to step 7.

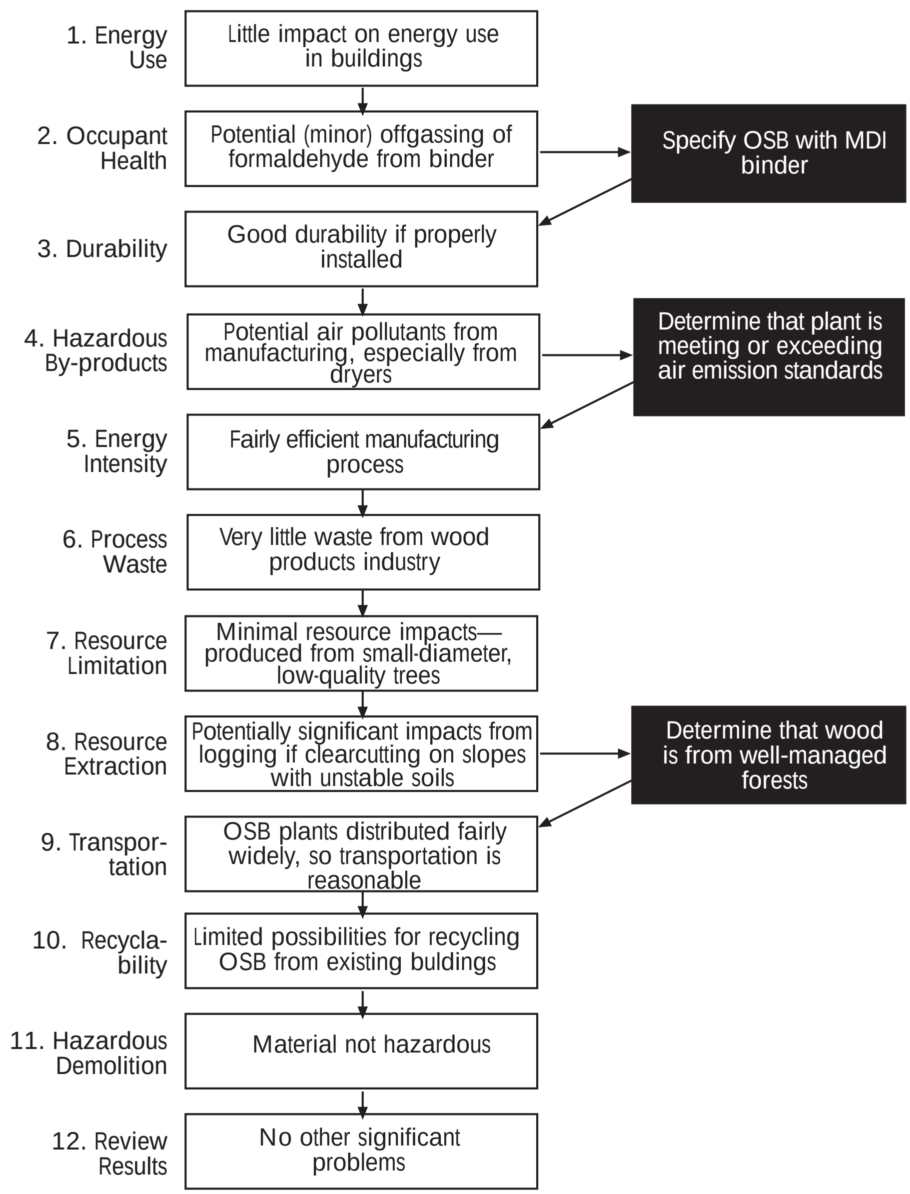
If significant amounts of solid waste are generated that are not readily usable for other purposes (tailings from mining of copper and other metals), seek alternative materials, or materials from companies with progressive recycling programs.

Further steps: raw materials

Step 7 – Resource limitations: Are any of the component materials from rare or endangered resources? If not, proceed to step 8.

If yes (endangered or threatened tree species), avoid these products, unless they can be sourced from recycled material.

Oriented-strand board sheathing



An application of EBN's Simplified Method to oriented-strand board (OSB) sheathing.

Step 8 – Impacts of resource extraction: Are there significant ecological impacts from the process of mining or harvesting the raw materials? If not, proceed to step 9.

If yes (damage to rainforests from bauxite mining for aluminum, or from certain timber harvesting practices), seek suppliers of material from recycled stock, or those with credible third-party verification of environmentally sound harvesting methods.

Step 9 – Transportation: Are the primary raw materials located a great distance from your site? If not, proceed to step 10.

If yes (Italian marble, tropical timber, New Zealand wool), seek appropriate alternative materials from more local sources.

Final steps: disposal or reuse?

Step 10 – Demolition waste: Can the material be easily separated out for reuse or recycling after its useful life in the structure is over? If so, proceed to step 11.

While most materials that are used in large quantities in building construction (steel, concrete) can be at least partially recycled, others are less recyclable and may become a disposal problem in the future. Examples include products that combine different materials (such as fiberglass composites) or undergo a fundamental chemical change during manufacture (thermoset plastics such as polyurethane foams). Consider the future recyclability of products chosen.

Step 11 – Hazardous materials from demolition: Might the material become a toxic or hazardous waste problem after the end of its useful life? If not, proceed to step 11.

If yes (preservative-treated wood), seek alternative products or construction systems that require less of the material in question.

Step 12 – Review the results: Go over any concerns that have been raised about the products under consideration, and look for other life-cycle impacts that might be specific to a particular material.

For example, with drywall and spray-in open-cell polyurethane foam insulation, waste generated at the job site is a potential problem that should be considered.

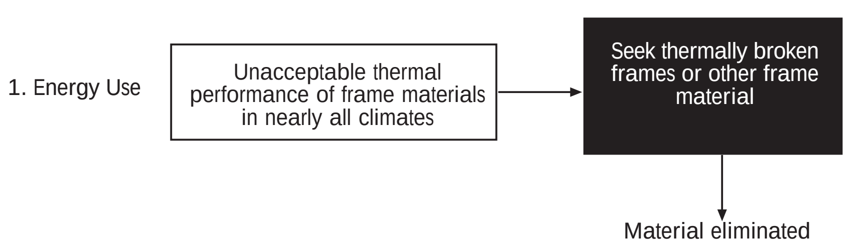
Conclusions

Selecting materials with the best environmental life-cycle and performance is not the only factor in designing green buildings—in most cases, it is not even be the most important. Nevertheless, it is an area where designers and specifiers can sometimes make a big difference in the overall environmental impact of a building for relatively little cost. It is also an area where building designers can influence manufacturing industries to improve their processes.

The steps of *EBN*'s simplified methodology won't catch all the environmental impacts of materials, but for most materials, this process will help a designer or specifier address the important concerns. Implementing these steps requires quite a bit of knowledge about the materials and their origin, so keeping up with the literature is important. Ongoing scientific research and changing environmental conditions are leading to new understandings of the issues, so the answers will never be final. Like all good design, environmentally conscious design demands a lifetime of learning. For material selection, the publications described here are a good place to start.

– Nadav Malin & Alex Wilson

Aluminum windows with thermally unbroken frames



With some materials EBN's Simplified Method may quickly lead to "knock-out criteria"—a term used by Architect William McDonough for conditions that make the use of the material flatly unacceptable.

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